Anoxic Alkaline Drain Treatment of Seeps Entering the Red River

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Abstract

The New Mexico Environment Department (NMED) conducted a two-year water quality investigation, funded in part by a U.S. Environmental Protection Agency 319(h) Grant, along the Red River, Taos County, New Mexico. The project culminated in a cooperative field demonstration project to mitigate and prevent future impacts of highly acidic, metal-loaded ground water seeps entering the Red River, near Questa. The NMED - Surface Water Quality Bureau, Nonpoint Source Pollution Section identified a number of sites where springs or perennial seeps deliver acid rock drainage via ground water which has been in contact with sulfide-rich hydrothermal rock scar areas or mine waste piles within the watershed. The seeps have a direct impact on the physical and chemical water quality and thereby effect the designated uses of the waterway. In-stream impacts include stream acidity, precipitation of calcium-aluminum cements, impairment of macroinvertibrate and fish habitat, and transport of a variety of dissolved and suspended heavy metals.

The field project involved the installation of selected Best Management Practices (BMPs) consisting of a set of Anoxic Alkaline Drain Passive Treatment Systems at a site along the Red River where several of the seeps are particularly active. One hundred seventy lateral feet (170') of trenches were dug below the local ground water level. The trenches were filled with limestone cobble, capped with a layer of clay, and reclaimed to road shoulder grade. Physical parameter and water chemistry monitoring is underway to measure an anticipated increase in pH levels and a corresponding decrease in the heavy metal content of the seeps. Favorable results may point the way to implementing this technology on several sites in this watershed, and around other abandoned mine or mill sites, or geologically active source areas throughout the state where acid rock drainage presents a pollution problem.

The project was a cooperative effort between NMED (project inception, design, coordination and follow up monitoring), the Unocal Molycorp Questa Molybdenum Mine (donated materials, equipment, and labor), the State Highway and Transportation Department (labor, heavy equipment and safety crews) and the Questa Ranger District, Carson National Forest (permitting).

Introduction

The Red River region of northern Taos County, New Mexico is recognized as one of the most beautiful tourist destinations and popular multiple use areas of our state. Visitors flock there in summer and winter for the recreation opportunities such as camping, skiing, hiking, back country touring, and of course, fishing. Environmental scientists, sportsmen, activists and local residents are concerned about environmental conditions threatening or impacting the region. Many citizens, including some of those in attendance at this ***1996 NM Conference on the Environment***, are involved with projects to improve and protect various aspects of the watershed. New Mexico Environment Department (NMED) staff participate in monitoring and field implementation projects and are responsible for municipal and industrial air and water quality permitting issues in the region. This paper presents information on attempts to mitigate particular aspects of nonpoint source pollution (NPS) of surface and ground waters by addressing acidic, metal-loaded seeps entering the river.

Location of study area

The Red River's headwaters begin as springs and snow melt from the highest terrain in the state. Beginning in the northern and eastern sides of the Wheeler Peak Wilderness (Figure 1), the river accumulates the flow from twenty one perennial tributaries along its route through the Taos Mountains of the Sangre De Cristo Range, westerly down to the Taos Plain and the Rio Grande Rift. Covering an area of 226 square miles, it is a major tributary watershed to the upper Rio Grande system. The site of this demonstration project lies in the middle reach of the river, between the towns of Red River and Questa (Figures 1 and 2), near the confluence of the Red River with Capulin Canyon, to the north, and Bear Canyon to the south.

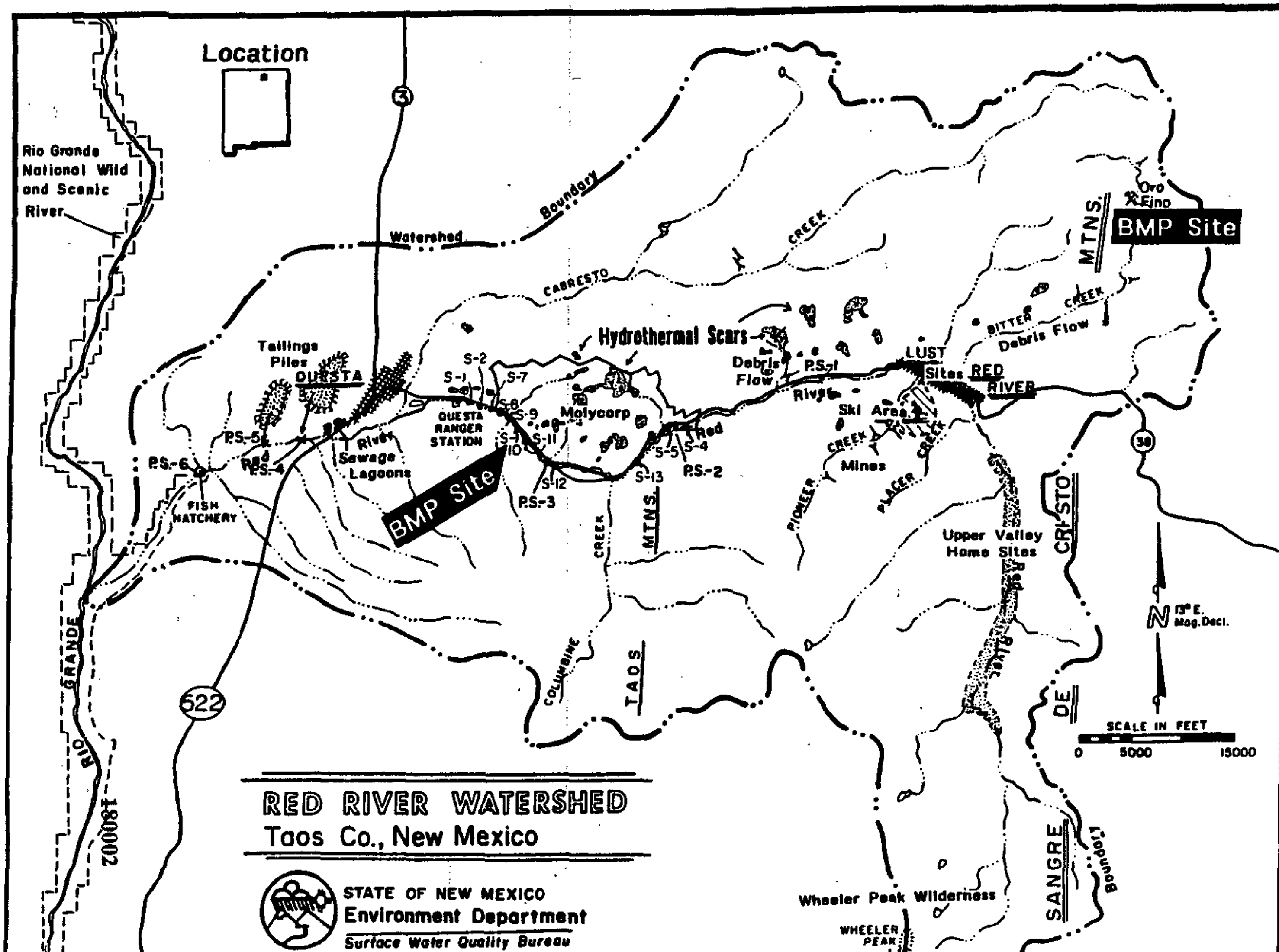

Fig. 1. Map of Red River Watershed showing locations of point and nonpoint sources of possible contamination to the Red [illegible]r.

EXPLANATION

POINT SOURCE POLLUTION:

PS-1: Town of Red River Wastewater Treatment Plant

PS-2: Molycorp Mill Site Outfall #005

PS-3: Molycorp Mine, Goathill Gulch Outfall #004

PS-4: Molycorp East Tailings Pile Outfall #002

PS-5: Molycorp Pope Lake/W.Tailings Outfall #001

PS-6: Red River Fish Hatchery (NMDG&F)

NONPOINT SOURCE POLLUTION:

S-1 to S-13: Red River Groundwater Seeps (ARD)

Hydrothermally Altered Volcanic Rock Scars

Molycorp Mine

Scattered Abandoned Mine and Mill Sites (Esp. Pioneer and Bitter Creeks)

Upper RR Valley Home Sites: septic tanks, leach fields

Town of Red River: Leaking Underground Storage Tanks (LUST)

Red River Ski Area

Town of Questa Sewage Lagoons

Landslide/ Debris Flow Gravels and Sediments (Bitter, Hansen and Hotentot Creeks)

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Background

In past years the Red River gained fame as one of the premiere trout fishing streams in the nation. The ground water resources of the area were known to be of the highest quality. Prior to mid-1960s, polluted surface water was rare, except during seasonal storm events when turbidity and sudden spikes of soil-derived metals temporarily contaminated the waters. As urban development and tourism increased and the local mining, cattle ranching and timber industries matured in the region, the impacts on surface and ground water quality have overwhelmed the Red River. Presently the watershed's designated or attainable uses as a high quality coldwater fishery, and source for livestock/wildlife watering and irrigation waters are not being met (NMWQCC, 1994). Environmental concerns include effluent from septic tanks and leach fields, leaking underground storage tanks, low pH levels, siltation, heavy metal loading in the stream from acid drainage, and loss of biological and riparian habitat (Slifer, 1996; Figure 1).

The headwater areas remain mostly high quality sources but the water delivered downstream into the Rio Grande is not as clear and clean as it once was. Several miles below the Town of Red River the water is frequently a distinctive cloudy blue-gray color, indicative of a highly stressed waterway. The lowermost reaches, designated as a part of the National Wild and Scenic Rivers System, have recovered as a spawning ground for big brown and cutthroat-rainbow trout, primarily due to stream dilution of pollution effects, but a variety of upstream NPS impacts, as well as seasonal turbid flood events, still threaten the river.

Identification of Impacts

The Red River watershed has become the focus of several field projects implemented by the NMED-Surface Water Quality Bureau (SWQB). The investigations are aimed at identifying, controlling or preventing NPS problems associated with mining impacts, ground water quality and stream channel restoration. During a recently completed two year project, funded in part by a Grant from the Environmental Protection Agency (EPA), the investigators evaluated the quality of the ground water which recharges the gaining Red River. Sources of impact were identified and corrective procedures known as Best Management Practices (BMPs) were designed and implemented. Project Manager Dennis Slifer sampled the various tributary stream sources and ground water wells along the main stem of the Red River and identified a number of sites where metal-loaded, acidic waters seep into the Red River. Approximately ten seeps were monitored for chemical changes through time. His conclusions are presented in a Final Project Report to the EPA Region 6, in preparation (Slifer, 1996).

Beginning below Cabin Spring, near the confluence of Columbine Creek, the river develops a milky blue-gray color due to an excess of dissolved and suspended heavy metals entering the river from both overland and spring or seep sources. Physical parameters such as pH and conductivity deteriorate within the same zone. Metals are mobilized from upland sources when oxygenated acidic waters contact sulfide-rich bedrock, soils or mining wastes. In the stream, the buffering capacity of the river assists in neutralizing the acid and the metals slowly precipitate out. Along certain river segments a white pasty material composed of calcium, aluminum and silicon accumulates on the stream bottom near where acidic spring or seep waters merge with stream flow. The compound contains *gibbsite* (aluminum hydroxide phyllosilicate). It effectively cements the stream bottom, sealing the substrate where macroinvertebrate insect life struggles to survive. While not technically "biologically dead", reaches accumulating this paste are very heavily impacted. Only high seasonal flows can temporarily scour the substrate clean. Fish are unable to thrive due to chemical stresses and lack of food. Currently there exists an absence of a reproducing fish population and a lack of favorable benthic habitat, except near the confluence with the Rio Grande. It was decided a BMP should be attempted to address both the geochemical and biological impacts.

Probable Sources of Contamination

A combination of interrelated geologic conditions and industrial practices very likely contributes to the development of the acid seeps. The complex geological setting involves Proterozoic metamorphic basement overlain by Tertiary sediments and intermediate volcanics. Episodes of caldera subsidence and injection of granitic plutons followed. Structurally, the area has been faulted, tilted and uplifted in response to Rio Grande rift extension. The intrusions were responsible for hydrothermal (hot water) alteration and significant ore mineralization in this district. Past mining operations for precious and base metals are scattered throughout the watershed. The Questa Molybdenum Mine dominates the landscape with its attendant open pit, waste rock piles, exposed ore-bearing zones, and the milling and tailings disposal facilities. There are numerous opportunities for degradation of water quality near a mining operation of this size, especially considering the mode of disposal of waste rock employed in the past. The management of the Questa Mine, while not taking responsibility for pollution problems along the Red River, is cooperating by monitoring and mitigating possible mine site pollution sources. They are collecting acidic seepage from waste piles, diverting it to the underground mine area. They have installed a set of monitor wells around the mine and tailings pile sites. Molycorp showed interest in NMED's demonstration project in order to determine if passive treatment systems should be constructed on their property for treatment of leachate from waste rock piles.

Additionally, the volcanic outcrop areas host a number of large and colorful ridges and hillside scars which are natural geological exposures of the hydrothermally altered rocks. Meteoric-hydrothermal systems related to the intrusions altered felsic volcanics to clay and deposited high grade pyrite (to 3%) in permeable host rocks (Meyer and Leonardson, 1990). The steep scar areas are a significant source of NPS pollution, yielding sulfidic sediments during storm events and releasing their naturally occurring ARD. Weathering promotes iron oxide formation and exposes new layers of sulfide-rich clays and altered volcanics which gravitate to the gentler slopes and stream bottoms. Vegetation rarely gains a foothold.

Current field work suggests the erosion of many of the natural scar areas was greatly accelerated by man's relatively recent activities: gold and molybdenum prospecting, establishing exploration drill roads, cutting adits and shafts into the colorful exposures of altered materials. Many recreational four-wheel drive roads and trails cut into these or similar materials, with the effect being erosion and runoff access to additional metal-rich soils and bedrock. There are "control" scars which appear to be untouched and these sites are not eroding on the same scale. They emit only occasional acidic runoff, far less than is seen in the prospected or traveled-over scar areas.

When air and water come into contact with either the widespread mine waste rock piles, the walls of the open pit mine or the exposed sulphide-rich erosional scars, the result can be generation of acid and mobilization of a suite of metals. When acidic water is introduced to soils or bedrock, it may leach additional available metals and emerge under or along the river as acidic, metal-loaded springs or seeps.

The NMED-SWQB project identified a number of seep source areas, generally along the north bank of the river, which are steadily delivering acidic water and heavy metals to the stream. Sampling reveals pH in the range of 3.0 to 4.1, and conductivity ranges from 1100 to 2400 umhos/cm. Analysis for heavy metals and water chemistry reveals a suite of dissolved and suspended metals, including Al, Cd, Co, Cu, Fe, Mn, Mo, Ni and Zn, at levels which exceed state and federal ground water quality standards.

The effort continues to better understand the relative contribution of polluted waters from the scar areas vs. the mining operations. Fingerprinting the acid waters is not a simple matter. Current analyses suggest direct runoff from mine waste contains greater sulfate, Al, Be, Mn, Zn, Cu, and Cd than waters from scar areas. A comparison of water chemistry of seeps downgradient of Molycorp's property, with those located upstream, shows a 3X increase of Al, Be, Cu, and Mn in the seeps below the mine and waste dumps area.

BMP implementation

On October 31 thru November 2, 1995, NMED-SWQB staff members Michael Coleman, Peter Monahan, Dennis Slifer, and Delbert Trujillo worked in tandem with Molycorp Questa Mine personnel, crews from the State Highway and Transportation Department, and the Questa Ranger District of the Carson National Forest in the installation of a BMP passive technology designed to improve the chemistry of the shallow ground water seeps.

The passive technology employed is known as **Anoxic Alkaline Drain Treatment** (AADTs). It was developed in the coal fields of the Appalachian and Atlantic Coast states to address acid waters escaping from abandoned or active coal mines and their pyrite-rich waste piles. The technology has previously been applied by NMED to only one other site in New Mexico, also within the Red River watershed. The treatment system is designed such that acidic waters low in dissolved oxygen will be intercepted by a buried trench filled with limestone (high alkaline grade, 80% calcium carbonate content) under continued anoxic (lacking oxygen) conditions. In theory, the seep water's pH will be raised from strongly acidic to less acidic conditions (a complete change to neutral or basic conditions is unlikely). Bicarbonate ions may be added to the water's chemistry. A significant portion of the dissolved or suspended metals should precipitate out uponcontact with carbonate rock and bicarbonate solutions in the trench, preventing the metals from being introduced into the Red River. In the long term, a downstream recovery of water quality and biological habitat is highly desirable.

NMED staff designed, coordinated and documented the BMP effort and will continue monitoring the seep areas. The installation involved a voluntary effort by Molycorp and the State Highway Department digging long, deep trenches along Highway 38, approximately two miles east of Questa. The trenches were placed on the northeast side of the river, adjacent to a particularly impacted active seepage zone near the Capulin Canyon tributary. The trenches are located on the highway road shoulder, ten to twelve feet above the level of the Red River. While it is an ideal site to attempt the BMP due to the presence of the active seeps, the logistics in the selected area were less than perfect. The available working area is only a few yards wide, making access difficult for the heavy equipment. Buried power and gas transmission lines occupy part of the areas originally intended for the BMP trenches.

Two distinct versions of acid seeps are present in the Capulin area. One style is referred to as "point seeps", where investigators identified individual discolored seep sites with small algae-filled pools along the rocky stream shoreline. The other form is a "seep front" which involves seepage accumulating within an abandoned Red River channel segment. The channel floor is iron oxide stained and saturated with acidic water but a discrete flowing seep source is difficult to identify. In this demonstration three trenches were situated immediately uphill, less than thirty feet from the point seeps (Figure 3). An alkaline trench was positioned eighteen feet from the channel seep front's eastern (upstream) end, but logistics prevented construction along that seep's western (downstream) reach, a distance of approximately 150'.

The trenches were dug to depths of 13-15 feet, into moderately consolidated streambank sediments. The trench lengths varied from 25' to 70' long. A total of 170 linear feet of trenches, in four segments were completed (Figure 3) along the 400'+ zone along the river which contains the seep areas. The trenches were dug as deep as possible while maintaining wall stability. When ground water was encountered, it was sampled and tested (analyses are pending). We could confirm that the same acidic conditions existed in ground water as those seen in the adjacent streamside or channel seeps. The trenches were partially filled with limestone cobble (2" to 6", rounded) delivered from near Tijeras, Bernalillo County (provided by Molycorp). A 20 mil thick polyethylene plastic sheet was secured over the limestone and a 2'-3' layer of bentonitic claystone (from near Antonito, Colorado) was placed on top of the plastic. Together, the plastic and clay form a cap over the limestone, aiding the acid/carbonate reaction in an anoxic environment. The trenches were backfilled with a clean fill dirt, surface graded, seeded and covered with a chopped straw mulch. The site presently gives no surface indication of the deep rock-filled trenches which underlie the area.

The channel seep infiltrates into sandy materials on its western (downstream) end. A small stand of acid tolerant wetlands vegetation (grasses, sedges and some woody shrubs) is established there. A future stage of the BMP installation may be further enhancement of the wetland area to assist the alkaline drains in finishing the pollution prevention process.

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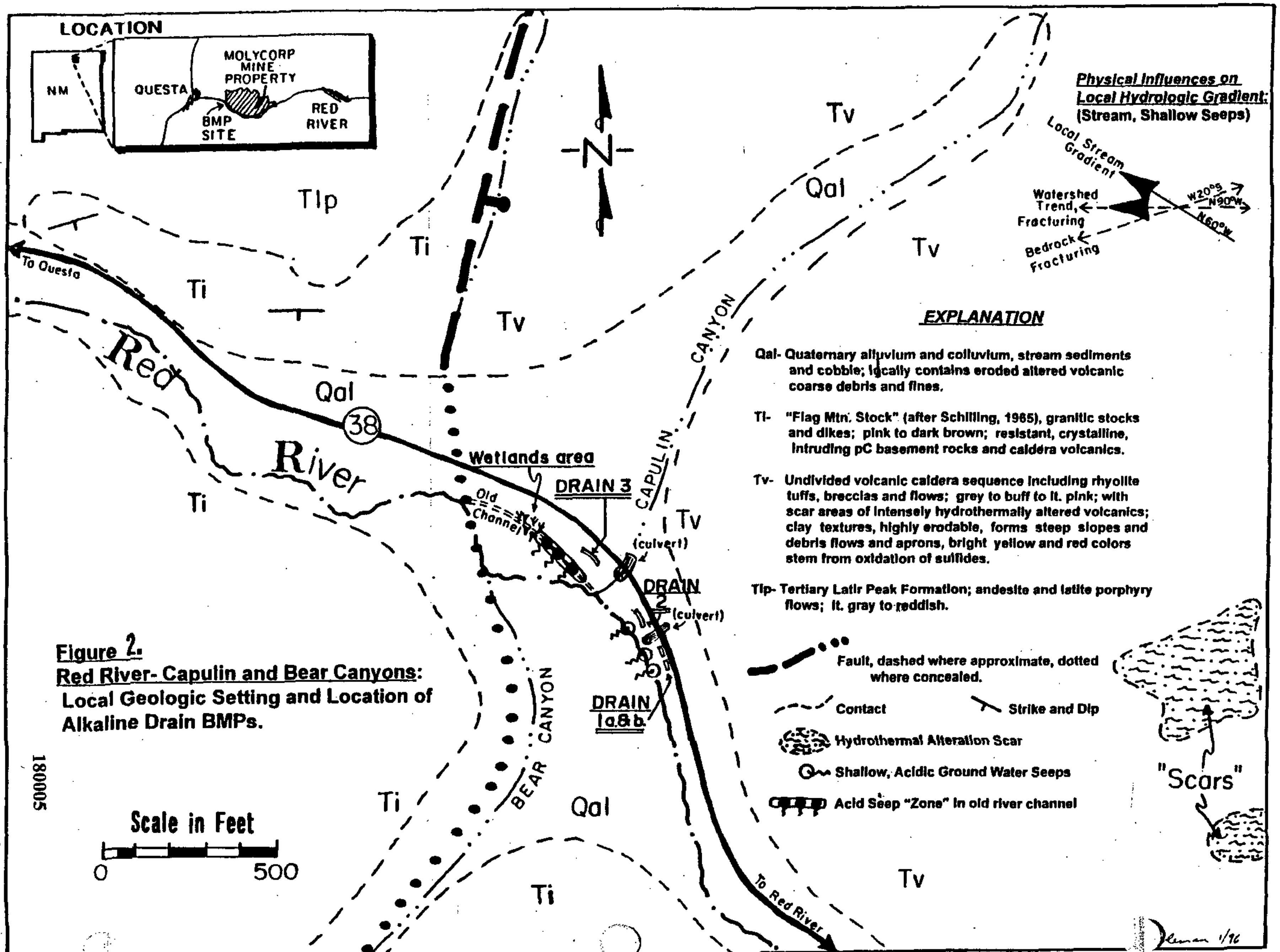

Figure 2.
Red River- Capulin and Bear Canyons:
Local Geologic Setting and Location of Alkaline Drain BMPs.

Results

To date, monitoring of the Red River-Capulin drains has not revealed any dramatic changes in screening parameters at the groundwater seeps.

Measurements taken before the drain installation were as follows (see Figure 3):
Red River: pH 6.92; conductivity 230 umhos @ 6°C.
Seep #10: pH 3.6; conductivity 1670 umhos @ 10°C.

During the excavation:
Drain #3 (groundwater): pH 3.6; conductivity 1700 umhos @ 12°C.

Following the installation, monitoring reveals a range of measurements (thru mid-Feb.1996):
Red River: pH 6.9 degrading to 5.0 (low flow); cond. 215-250 umhos
Seeps: pH 3.27 to 3.8; cond. 1100-1450 umhos

Analysis

This slightly improved "trend" must be maintained and continue over a period of years for the treatment project to claim any success. Laboratory analysis results are still pending and a new round of water chemistry sampling is slated for this spring. If those analyses show a decreased dissolved and suspended metal in the seeps, some success can be claimed.

Considering the trenches were installed in late fall, at a time when stream and ground water are at their lowest base flow levels, the water may not yet be filling the limestone portion of the trench. The increased dissolved oxygen content of the water intercepted during construction may not have subsided, postponing the time at which the treatment can proceed under anoxic conditions. If it had been possible to dig deeper trenches, intercepting a larger interval of the water table, we might have seen more immediate results. It has been suggested that the coarse size of the limestone clasts was larger than the design called for and may be inhibiting the drains' function.

When peak flow resumes on the Red River this summer, the point seep areas will disappear as water flows into bank storage during a losing phase of the seasonal flow. Once the peak flow period subsides, gaining stream conditions return and the outward seep flow is expected to resume. It is hoped a favorable water storage year will raise the local water table and force more of the acidic water into direct contact with the alkaline system.

Previous applications

In 1993 an alkaline drain bench-scale project was installed by Bob Salter of the SWQB, with the support of the Amigos Bravos and the Rio Grande Restoration conservation groups. The BMP site was the abandoned Oro Fino Mine, along upper Bitter Creek, a tributary to the Red River. At the mine site snowmelt and rain run off through a modest pile of particularly sulfide-rich mine waste and tailings materials. The runoff develops into an acidic, metal-loaded streamlet before entering Bitter Creek. Oro Fino's small alkaline trench has proved effective in improving the chemistry of the seep waters from pH 1.5-3.6 to a near neutral 6.8. Conductivity has improved from 3600 down to 650 umhos/cm, and dissolved elements such as sulfates, Al, As, Cd, Co, Cu, Fe, Mo and Zn are greatly reduced so the runoff again meets water quality standards. The Oro Fino trench was a smaller, more straight forward BMP installation than the Capulin sites. The drain could be constructed right at the seepage source. The Red River site presented a number of logistical, depth and positioning problems, and the volume of acid seepage is much greater than at Oro Fino, but we remain hopeful of comparable favorable results.

Conclusions

It is recognized this BMP installation project pursued the symptoms of the acid drainage problem rather than directly confronting the source cause of the impairment. Resolving the total acid generation problem in

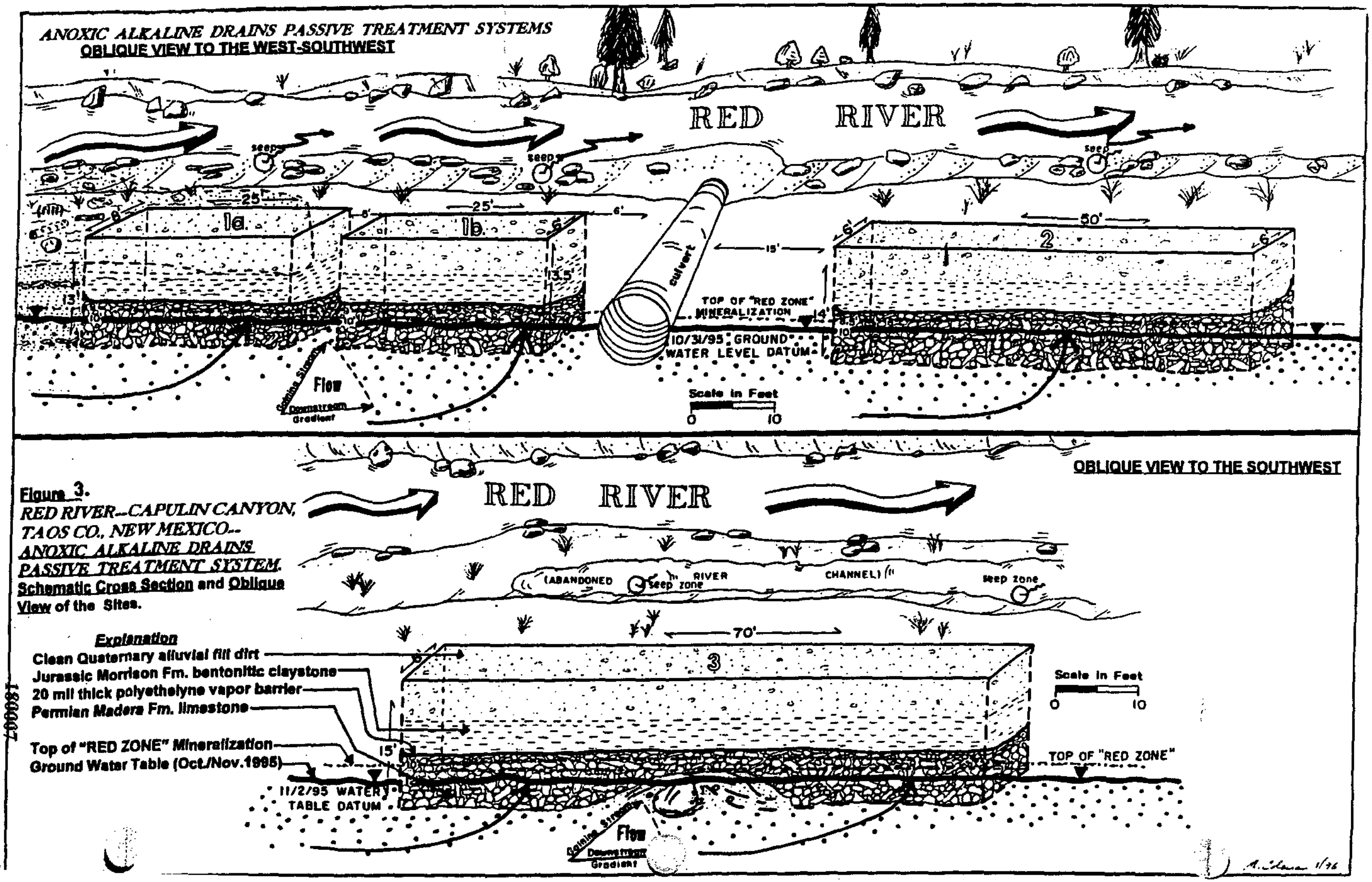

Figure 3. *RED RIVER--CAPULIN CANYON, TAOS CO., NEW MEXICO-- ANOXIC ALKALINE DRAINS PASSIVE TREATMENT SYSTEM.* Schematic Cross Section and Oblique View of the Sites.

the Red River watershed will require active participation of the mining interests and equal attention to the vast areas of hydrothermal outcrops, administered by the Forest Service. This demonstration project and the principles behind it (if they prove some measure of success) may have widespread application adjacent to the active or abandoned mine sites elsewhere in the Red River watershed or in other areas of New Mexico where acid drainage from either mine sites or geological sources has become a serious water pollution problem. Built in series, with natural or constructed wetlands included in the overall design, this technology has certainly proven its effectiveness in other settings (Turner and McCoy, 1990; Nairn and others, 1992). The NMED Surface Water Quality Bureau and US Environmental Protection Agency are seeking additional demonstration sites and are hopeful of applying the Anoxic Alkaline Drain Treatment System technology in future water pollution prevention projects.

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Red River-Capulin Canyon area Anoxic Alkaline Drains.

***2.5 mi. E. of Questa, on south shoulder NM Highway 38**			*File: RRDrains.wkb (excel 5.0)*		
Taos County, New Mexico				**SAMPLING**	
Location/Description	**Dimensions (Volume)**	**Depth to "Red Zone" Fe oxide mineral'n.**	**Depth to ground water**	**Physical Parameters**	**Lab Analysis**
					(all results pending)
Drain #1a.	**25'Lx8'Wx13'D**	**9'**	**10'**	*Seep sample-10/30/95:pH 3.5,*	**Metals:dissolved &**
(Easternmost trench	**(2600 ft3)**			cond. 1500 umhos @ 10°C.	**total;**
on Seep #10E, east of					**Cations/anions;**
local highway culvert)				**Drain 1: pH = 4.21, conduct'y**	
				1650 umhos./cm @ 14°C.	
Drain #1 was originally designed to be 50' long. After breaking ground the crews recognize				**(Compare 10/30/95 stream**	
that this segment of streambank has been washed out by previous flooding. Streambank				**conditions, : pH=6.92;cond.**	
and road base repairs were made with a wide variety of materials, including a mix of fill				**230 umhos @ 6°C.)**	
dirt, *rock boulders*, large tree trunks and wooden and plastic trash. *Digging* trenchs into					
these mixed materials proved difficult as the trench sides and ends were very unstable				*Best post-drain measurements.*	
and prone to collapse. Drain #1 was split into a. and b. segments (with a 5' wide zone in				*seep 10E. to 2/96: pH 3.77:*	
between) to stabilize the trenchs. The extent of the "repaired" ground carries just a few feet				*cond. 1200 umhos/cm @ 8°C.*	
into the area of trench #1b. where normal overbank stream sediments again form the north					
bank of the Red River. Trench stability was not a problem elsewhere .					
Drain #1b.	**25'Lx6"Wx13.5'D**	**9'**	**10'**	**(parameters as above)**	
(Continuation of drain	**(2025 ft3)**			**(Drain #1B not sampled**	
intercepting Seep #10E,				**during installation)**	
still 6' east of culvert.)					
Drain #2	**50'Lx6'Wx14'D**	**8.5'**	**10'**	*Seep 10W:pH3.47,cond.1500.*	**(pending)**
(West of #1a&b, begins	**(4200 ft3)**			**Drain #2: pH = 3.83, cond.**	**Metals:dissolved &**
15'W. of culvert, posit-				**1500 umhos/cm @14°C.**	**total;**
ioned to intercept Seep				*Best post-drain seep #10W*	**Cations/anions;**
#10W, the portion that				*samples. thru 2/96: pH=3.79:*	
is west of the culvert.)				*cond. 1200 umhos/cm @ 9.6°C.*	
Drain #3	**70'Lx6'Wx15'D****	**10'**	**12'**	*Seep #9,before instal'n.: pH*	**(pending)**
(Located 300' west of	**(<6300 ft3)****			*3.3, cond.1800 umhos / 10°C.*	**Metals:dissolved &**
Drains 1&2, inside the	**(**a large boulder**			**Drain #3: pH 3.6, cond. 1700**	**total;**
highway guard rail. It is	**in central part of**			**umhos @ 12°C.**	**Cations/anions;**
positioned to intercept	**trench was not**			*Best post-drain samples: pH*	
the eastern end of the	**removed,making**			*3.79: cond. 1200 umhos/cm*	
seep zone filling the	**for a 3' long seg-**			*at 9.6° C. thru 2/96)*	
"*old* Red River channel"	***ment which is only***				
of Seep #9)	**11' deep)**				

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